
Questions are of values as indicated in the margin
Answer question number **one** and any **three** from the rest

1. Answer any **eight** questions

$$8 \times 3 = 24$$

- (a) Can a charged particle move through a uniform magnetic field without experiencing any force? Explain.
- (b) If no work can be done on a charged particle by the magnetic field, how can the motion of the particle be influenced by the presence of a field? Explain.
- (c) Show that the electric field (\vec{E}) and magnetic field (\vec{B}) remain invariant under gauge transformation. Which conservation law is linked with gauge invariance of electromagnetic fields?
- (d) An object moving in two dimensions has a position vector $\vec{r}(t) = a \sin \omega t \hat{i} + b \cos \omega t \hat{j}$, where a , b and ω are constants. How far is the object from the origin at time t ? Find the velocity and acceleration as function of time for the object.
- (e) If a current is passed through a spring, does the spring stretch or compress? Explain.
- (f) Check whether $\vec{B} = 3x\hat{i} - 5y\hat{j} + 2z\hat{k}$ can represent a magnetic field or not ?
- (g) Show that the electric field \vec{E} is discontinuous at a surface which carries charge density σ .
- (h) Show that magnetic forces do no work.
- (i) A metal disk of radius a rotates with angular velocity ω about a vertical axis, through a uniform magnetic field B , pointing up. A circuit is made by connecting one end of a resistor (R) to the axle and the other end to a sliding contact, which touches the outer edge of the disk. Find the current in the resistor.

-
2. (a) Find the electric field a distance z above the midpoint of a straight line segment of length $2L$ which carries a uniform line charge λ . What is the value of the electric field for this case in $L \rightarrow \infty$ limit.
- (b) Calculate magnetic field due to a current carrying infinite wire by using Ampere's law. Explain why some of the components of the magnetic field are zero?
- (c) State and briefly discuss Biot-Savart law. Is it valid for time varying current?

4+4+4=12

3. (a) Consider a system of N discrete charges with magnitudes q_1, q_2, \dots, q_N located at $\vec{r}_1, \vec{r}_2, \dots, \vec{r}_N$ respectively. Show that the potential energy of this system is

$$U = \frac{1}{2} \sum_{i=1}^N q_i V(r_i),$$

where $V(r_i)$ is the potential at \vec{r}_i (location of q_i) due to all the charges.

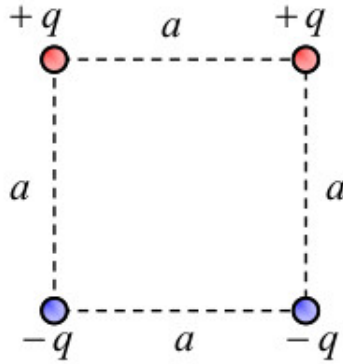
- (b) Three charges $+5Q$, $-5Q$, and $+4Q$ are located on the y -axis at $y = +4a$, $y = 0$, and $y = -4a$, respectively. The point P is on the x -axis at $x = 2a$.
- How much energy did it take to assemble these charges?
 - What are the x , y , and z components of the electric field \vec{E} at P ?
 - What is the electric potential V at point P , taking $V = 0$ at infinity?
 - A fourth charge of $+Q$ is brought to P from infinity. What are the x , y , and z components of the force \vec{F} that is exerted on it by the other three charges?

4+(2+2+2+2)=12

4. (a) Starting from the Maxwell's equations prove that the electromagnetic fields satisfy wave equations in vacuum.
- (b) Define plane wave with the help of a diagram. Using Maxwell's equations show that plane electromagnetic wave is a transverse wave.
- (c) Two infinite parallel planes carry equal but opposite uniform charge densities $\pm \sigma_0$. Find the field in each of the three regions: (i) to the left of both, (ii) between them, (iii) to the right of both.

4+(2+3)+3=12

-
5. (a) Obtain the expression for bound surface charge density (σ_b) and bound volume charge density (ρ_b) inside a dielectric where \vec{P} is the polarization vector of the dielectric substance.
- (b) Using the expression of bound volume charge density (ρ_b) establish the relation between electric field \vec{E} and displacement vector \vec{D} inside a dielectric material.
- (c) Choosing the reference frame at the centre of the square, calculate the dipole moment of the a system of four point charges of the same magnitude, but with a pair charge sign alternation, placed in the corners of a square systems as shown below:



$$4+4+4=12$$